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Effects of Land Use/Land Cover Changes on Rocky Desertification-A Case Study of a Small Karst Catchment in Southwestern China

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Abstract

Based on extraction of environmental information from lake (reservoir) sediment, this paper carried out systematic studies on effects of land use/land cover changes on soil erosion in last 40 years in Shibanqiao catchment of Guanling County, located in the southwest of Guizhou Province. Seven sediment cores were retrieved and analysis of activity of 137Cs of sediment samples was undertaken. The information of soil erosion in each phase was deduced, and then integrating it with land use/land cover changes in corresponded phase, the author took a further step to interpret the effects of land use/land cover changes on soil erosion. Such conclusions were drawn: (1) the rate and amount of soil erosion is related not only with land use/land cover regime but also with whether there are abundant erodible sources provided for erosion. (2) During 1960 to 1978, in the beginning of land use change, naturally selective erosion was dominant. Then the percentage of surface soil erosion increased, and became dominant in the subsequent phase. Soil erosion was decreased but rocky desertification expanded in a higher rate. So it can be deduced that there was a lag between the development of rocky desertification and soil erosion;(4) The accelerated soil erosion resulted from the stir of soil during the implementation of ecological engineering was detected between 1990 to 2002, in view of which，a suggestion was put forward in this paper that ecological constructions and engineering towards water and soil maintenance should pay attention to the problem of soil erosion followed, especially should avoid the stir of soil.

Key words: land use/land cover changes (LUCC); extraction of soil erosion information from sediment; environmental effect; soil erosion; Karst mountainous region

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1. Introduction

Land use and land cover changes(LUCC) project promoted in IGBP and IHDP now has grown up to a discipline(Turner Ⅱ et al.,1995), land change science. It was presented in Land research in IGBP Ⅱ that ecosystem functions and services were changing under the impact of LUCC. Soil erosion is a typical process of land degradation and a main environmental effects of LUCC. Soil erosion and corresponding sedimentation was well introduced in agricultural history. But there is much uncertainty in the extent, amount and rate of erosion and sediment and their influences on economy and society. And the continuous temporal serial erosion information is very lacking. Reservoir or lake sediment, which is the sink of material of the earth surface conserving the information of environment change and the interaction succession between human and nature continuously and precisely, which can compensate the scarce of history records(Brenner *et al.*, 1994; Wang S M et al.,1998).

In view of the severe scarce of soil erosion record in most area in China, this paper took Shibanqiao catchment, where Karst typically developed, as a case to carry out study combining study of LUCC and change of reservoir sediment to find the effects of LUCC on soil erosion. The sediment and soil erosion information through such methods can both provide base data of soil erosion in Karst area and make a try to find a new way to study the erosion effect of LUCC in a relative long temporal scale.

2. Study area and sampling

2.1. Study area

Shibanqiao catchment was located in Guanling County of Guizhou Province, where rocky desertification was most severe. Reclaimed wasteland wide distributed in the whole catchment. Shibanqiao Reservoir was built in the end of 1958.The area of the catchments was 5.76 km^2 .There was no natural river in the catchment and the reservoir mainly depended on precipitation. The sediment of the reservoir had never been disturbed since it was built.

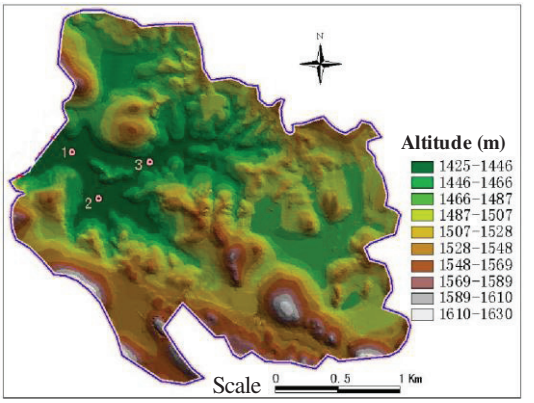


Fig.1 Sampling points in Shibanqiao reservoir

2.2. Sediment Sampling and Testing

Sediment samples were collected in Shibanqiao Reservoir on 22rd, March, 2003. The sample sites were showed in figure1.Three sediment cores were collected in each site. The measurement used in sampling was imported from lake and marsh institute of Institute of Lake and Marshes in Australia.

The sediment columns were sliced by 1cm and the samples were sealed up in plastic bags. We selected one column after pre measurement of those columns to carry out experiment in laboratory. The activity of 137Cs of each sediment sample was obtained by multi-channel Energy Dispersive Spectrometer and GC5019 coaxial Ge detectors.

3. Dating by 137Cs and estimation of soil and sediment rate of study area

From the distribution of the activity of ^{137}Cs with depth of sediment column, we can see three peaks well corresponding to 1964, 1974 and 1986. The total distribution was also accordance with related studies in the same altitude in karst area (Wan G.J., 1990). So we can date by the location of peak value

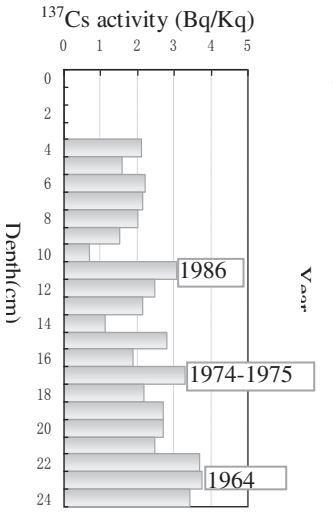
of ^{137}Cs and estimate sediment rate(table1,figure2 and figure 3).From the result, we can see that the sediment rate was quicker between 1962 to 1975 than that between 1975 to 1986,and it was quickest between 1986 to 2002.

Table 1 Sedimentation rates based on age information by ^{137}Cs in Shibanqiao Reservoir

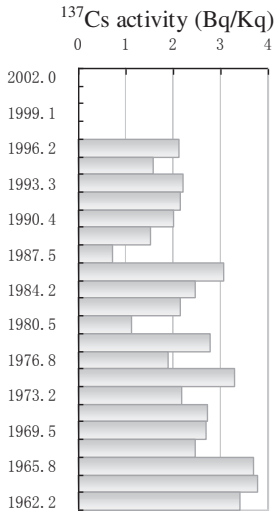
Dating	Depth (cm)	Sedimentation rate		Mass depth (g/cm^2)	Sedimentation rate	
		Period	Sedimentation rate (cm/a)		Period	Sedimentation rate($g/cm^2 \cdot a^{-1}$)
1964	23	1964-1975	0.643	19.80	1964-1975	0.5018
1974	17	1975-1986	0.55	14.28	1975-1986	0.4773
1986	11	1986-2002	0.688	9.03	1986-2002	0.5644
		Mean value	0.625		Mean value	0.519

4. Environmental effects of land use changes in the past more than 40 years

According to change of sediment indices, we found the corresponding land use data, including aerial images with a scale of 1:50 000 taken in 1960 and taken in 1978 with a scale of 1:10 000, two land use maps of scale 1:10000 measured in 1989 and 2003 respectively. Based on GIS and RS technique, we drew four land use maps of different periods. Changes and transformation of land use types were also obtained by statistic analysis. Combined land use and land cover changes data with environmental information extracted from sediment in corresponded periods, we found the relationship between them to study the impacts of land use changes on soil erosion, composition of eroded material and erosion process.



F.ig.2 Specific activity distribution of ^{137}Cs in sediment core



F.ig.3 Dating by sediment samples in core

The total land use and land cover change amount kept decreasing from 1960 to 2003 and became stable after 90s (Figure 4). We divided the study period into three phases according to soil erosion information extracted:

4.1. From 1960 to 1978

It was the beginning of destroying forest and grassland to expand cropland. Cropland increased 3.4 percent from 1960 to 1978, of which 57.5 percent of forest and 35.2 percent of grassland converted to cropland. The area of rocky deserted land increased 10.39 hm^2, which occupying 12.5 percent of the total area. We could deduce that land could resist erosion in some extent at the beginning of cultivation of forestland and grassland. The content of organic material of eroded resources was high. The soil erosion developed in natural selective erosion process, which was loose organic material, fine clay and other fine particles in the earth surface were eroded firstly.

In this period, natural vegetation was destroyed and human-made soil erosion quicken up. As a result, the earth surface became coarser and leanness. The area of rocky desertification expended.

4.2. 1978-1989

In this period, land use changes were similar with that between 1962 and 1978, but the change extent decreased. There was 31.2 percent of woodland changed, of which 84.2 percent transferred to farmland. For grassland, 30 percent of it changed, of which 82 percent transferred to farmland. The cover rate of farmland changed rapidly. It was mainly because that with the expense of rocky desertification, farmland became urgent. Farmer had to increase land used degree. Besides, the increase of bared rock resulted from water and soil erosion may also deduced decrease of crop cover rate. The area of rocky desertification expanded 9.43 hm2, which was more rapid than the first period.

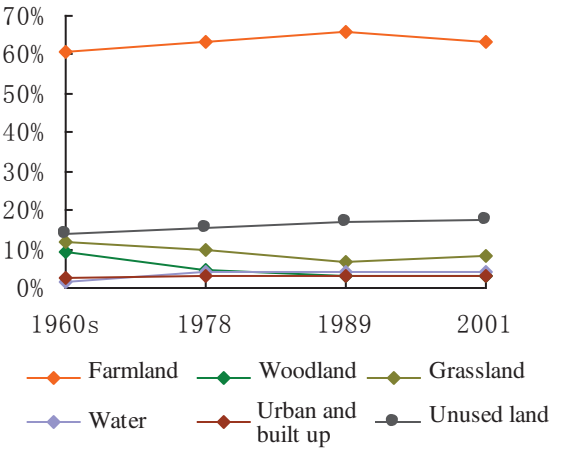


Fig.4 LUCC from 1960 to 2003 in Shibanqiao catchment

The soil erosion rate decreased relatively in this period, which mainly because of less and less coarse surface soil to be eroded. In fact, rocky desertification area expanded in a higher rate. We can see that rocky desertification usually lagged behind the soil erosion.

In this period, the erosion of surface soil was severe and rocky erosion picked up speed of expansion. The maximal soil erosion amount was been reached.

4.3. 1989-2001

In this period, farmland, woodland and grassland increased slightly, which was caused by returning cultivated farmland into woodland around the reservoir. The increase of grassland was mainly caused by degradation of woodland and restoration of barren land. The broad leaved tree planted in the early of 1980's has grown to forest. But the tree species was less and grass was sparse distributed under the tree. The cover rate of crop increased.

The soil erosion rate still increased in this period, mainly because of plantation and slope face regulation around the reservoir. In the process of slop face regulation and the dig of tree pit, the soil under the earth surface was brought to the surface and the sparse material increased. Besides, the new sparse material was near the reservoir and can reached reservoir easily. So, the soil erosion rate and erosion amount increased evidently

With the development of vegetation, it will control soil erosion more and more evident. The land suffering high risk of soil erosion had become entirely desertification. The expansion rate of rocky desertification began decreasing.

5. Conclusion and Discussion

5.1. Material in landsurface is the key factor determining the rate and amount of soil erosion

In Karst area, whether there is erodible soil is the key element determining the rate and amount of erosion. Between 1978 and 1990, the expansion of rocky desertification was the most, but the erosion

amount was low. It is just because that erodible surface soil kept decreasing with more and more area becoming barren.

5.2. Develop of rocky desertification was lag behind the soil erosion

Between 1962 and 1978, land use change was the most. In the beginning, the land surface was not easy to be eroded. The eroded material was mainly composed by loose and fine grain in the land surface. Between 1978 and 1990, the rate and amount of erosion decreased, but the expansion of rocky desertification was the most. Develop of rocky desertification was lag behind the soil erosion.

5.3. The surface land should not be disturbed in Karst region

Between 1989 and 2003, land use change was less than the other two periods and the cover rate of vegetation increased. But the soil erosion amount reached the maxima value. Plantation and returning cultivated farmland into woodland brought severer erosion in the beginning. We should take some measure to defend soil erosion in the beginning of the engineering.

5.4. Extracting soil erosion information from sediment is an effective method

Dating with 137Cs and combined with hydrologic data, sediment amount in each period could be estimated. The result of this paper can provide initial basic data for studying local soil erosion and sediment. Also, the authors tried to use a new method in related studies in Karst region and the temporal scale could be extended in land use and land cover study by this method.

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